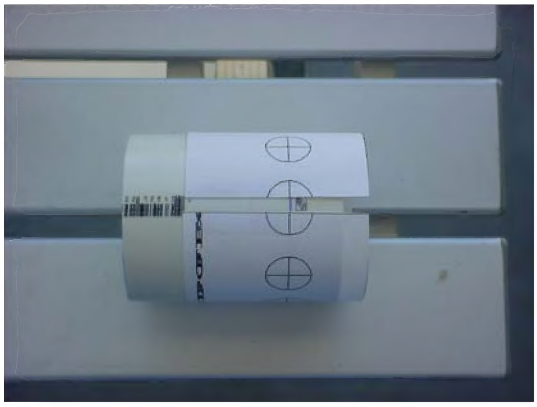
KNO3 / Sorbitol J-425 Segmented 3-Grain Motor Construction Tutorial

NOZZLE ASSEMBLY (see note 1)
(I use a nozzle form that I made out of 2-1/2" solid PVC that I machined on a lathe for more consistent nozzles, however, Dan's technique also works well.)

1. Start by cutting a 3" length of 2" Sch 40 PVC pipe for the nozzle assembly.
2. Measure ¾" from one side and draw a line all the way around the 3" piece of 2" PVC that you just cut. This line will be the centering line for the nozzle retaining pins that will be molded into the nozzle.

3. Using the hole template provided by Dan from Inverse Engineering, tape the template onto the 3" piece of PVC with the centerline of the holes aligned with the centerline that was drawn around the PVC.



4. Drill out the holes using a 5/8” Forstner bit and remove the template.

5. Clean up any remaining flashing using a razor knife.
6. Using Medium Grey PVC cement, glue the “hole” side of the 3” piece of PVC into a 2” PVC Slip Coupling and let dry according to the instructions provided on the can of cement.

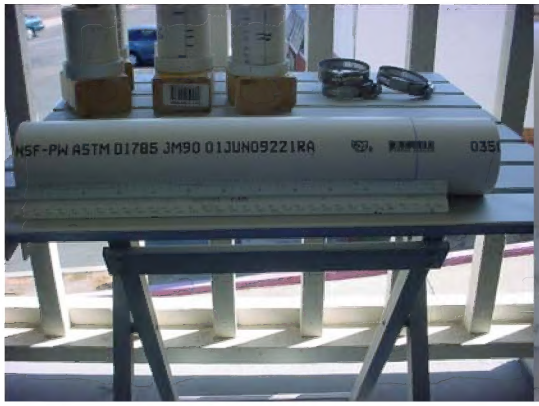
7. Once dry, using the information provided by Dan from Inverse Engineering for the nozzle mold, center the nozzle assembly that was just made over the nozzle mold.

8. Mix PourStone (Home Depot) according to the manufacturer's instructions and fill the nozzle assembly up to the top of the 2" PVC in the coupler and let dry for 45-60 minutes before removing from the mold.

9. Remove the nozzle assembly from the mold.
10. Remove the paper from the nozzle assembly.
11. The nozzle assembly in now complete.

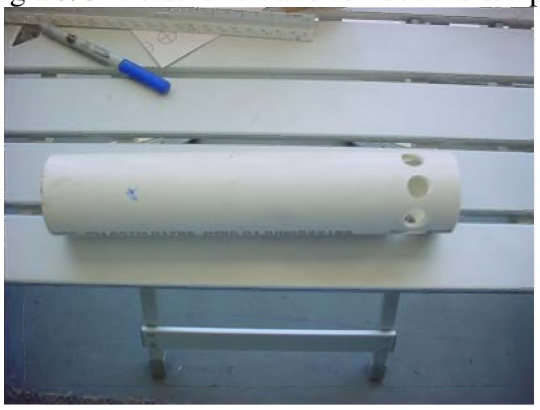
MOTOR CASING (see note 1)

1. Cut an 11-1/2" section of 2" Sch 40 PVC pipe.



2. Measure back 1-1/8” from one end and draw a line around the pipe.
3. Using Dan’s hole template, tape the template to the PVC with the centerline of the holes aligned with the line that you just drew.

4. Drill the holes using a 5/8” Forstner bit and remove the template.



5. Clean up any flashing that remains using a razor knife.
6. Mark the end with the holes in it “TOP” and the other side “BOTTOM”.

7. The casing is now complete.

PROPELLANT GRAIN TUBES

1. Using Red Rosin Paper, available from Home Depot, cut a 14”x 36” wide strip.

2. Test-roll the strip around a 24” length of 1-1/2” Sch 40 PVC pipe. The straighter the cut on the paper, the straighter the tube will be.

3. After test-fitting the paper around the pipe, insert the tube and PVC former into the 2” PVC pipe to make sure it fits. It should not be tight to push in, it should go in easily. If you have to force it in, it is too tight. Unroll a little bit at a time and cut off the excess and re-check the fit. After a satisfactory fit is achieved, unroll the paper all the way except for the last wrap.

4. Using 3-M spray adhesive, spray the entire length of exposed paper, (on the inside) and then re-roll the paper tightly around the pipe. This tube will be for the propellant grains.
5. Cut one end as square a possible using a razor knife.

6. Measure every 3 inches and make a mark using a fine point marker.
7. Draw a line around the tube at every 3" mark.

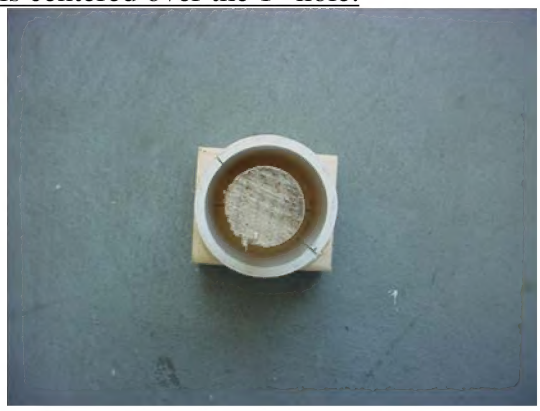
8. Cut the tube around these lines using a razor knife.
9. You should have 4 3" tubes.

10. The grain liners are now complete.

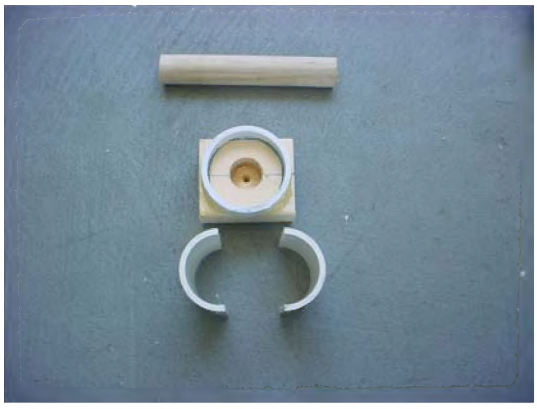
GRAIN CASTING FIXTURES

I used a 2x3's for my bases, but you can use whatever you would like for your bases.

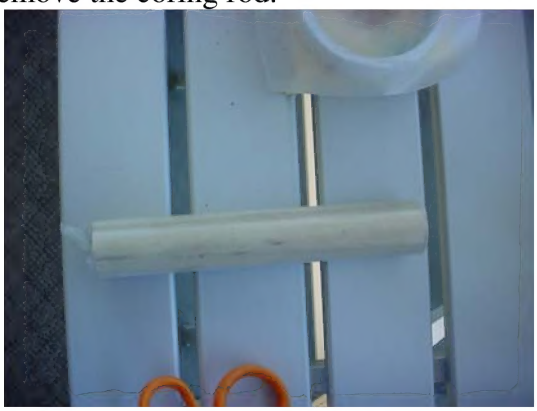
1. Cut a 3-4" block.
2. Drill a 1" hole in the center of the block.
3. Cut a ½" wide ring off of a 2" slip coupling and epoxy it over the 1" hole. Make sure that this ring is centered over the 1" hole.



4. Cut a 3" long piece of 2" PVC pipe and cut it in half length wise. This will help aid when separating the grain from the mold.
5. You will also need 2 hose clamps (Home Depot) that will fit around the 2" PVC. These will keep the pipe halves together tightly while you are casting the grain.
6. Cut a 6" long piece from a 1" dowel (Home Depot). This will serve as the core for the fuel grain.

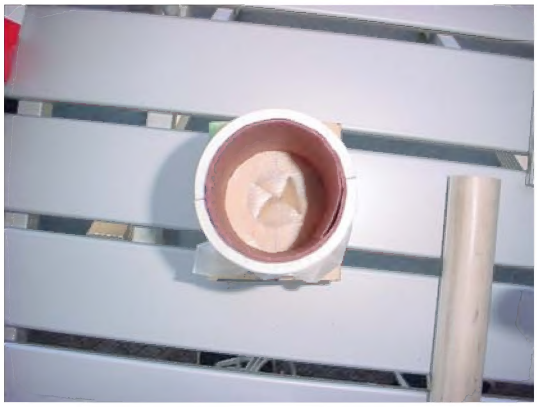


7. Wrap the dowel with one wrap of wax paper and tape it to itself. This helps when you are trying to remove the coring rod.



8. Place a piece of wax paper over the 2” coupling and press the cut PVC pipe over this until is seated against the wood base.

9. Using a razor knife, cut an “X” over the 1” hole in the base and inset the 1” bore rod into the hole.



10. Place a completed paper grain tube into the 2” PVC and using the 2 hose clamps, clamp the halves together. (Hose clamps are omitted for clarity.)

11. The casting fixture is now complete.

12. You need to make at least 3 of these casting fixtures in order to cast all 3 grains at the same time.

PROPELLANT MIXING

For this motor you will need to mix up 2 pounds of dry propellant. The ratio is 65/35. 65% KNO3 and 35% Sorbitol.

1. Start by measuring out 589.55 grams of KNO3.
2. You will need to grind this up into a fine powder using a coffee grinder. Grind up small amounts at a time, dumping the ground up mixture into your mixing pot.
3. After all of the KNO3 is ground up and added, measure out 317.45 grams of sorbitol. You do not need to grind this up.

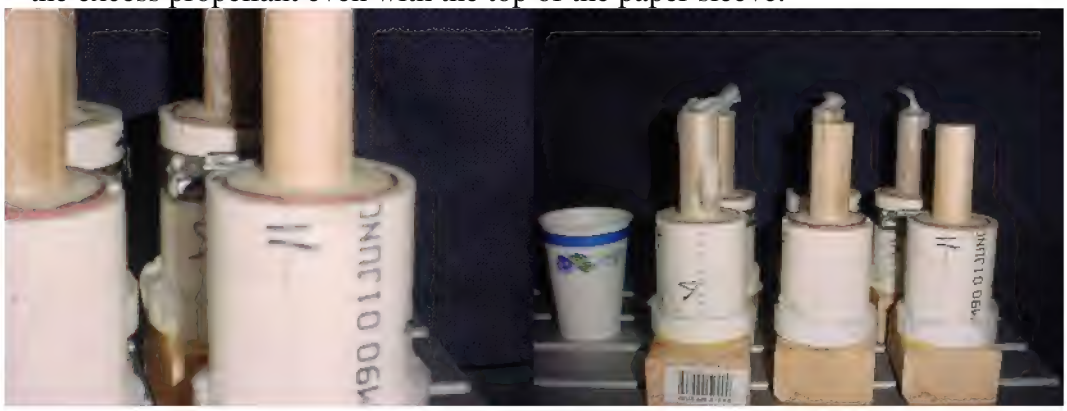
4. Add the sorbitol to the mixing pot. **AT THIS POINT, THE MIXTURE IS FLAMMABLE!!!**

5. Melt this mixture using whatever means that you use, however, I recommend using Dan's set up. He uses a wok that he sets to 300 degrees with wax in it. The wax serves as a way of transferring the heat to the mixing pot. The temperature is controlled by the wok. This setup helps to reduce the possibility of overheating the mix, causing it to self-ignite. REMEMBER TO KEEP MIXING THE PROPELLANT AT ALL TIMES TO GET A HOMOGENOUS MIXTURE!!

6. After the mixture is COMPLETELY melted, get one of the completed casting fixtures and scoop small amounts of propellant into the molds. This can be tricky until you get the hang of it. Fill the paper mold all the way to the top plus a little extra.

7. Repeat for the 2 other grains.
8. Set the grains off to the side to cool.

9. After about an hour, you will need to trim the top of the grains. If you do this while the propellant is still warm, it will be easier. Using a razor knife, trim off the excess propellant even with the top of the paper sleeve.



10. Let the grains harden for a few hours before removing them from the molds.
11. After they are hardened, remove them from the mold.
12. Start by removing the PVC from the base. The 2 halves will be easy to separate from the fuel grain.

13. Then remove the 1" coring rod.

14. Remove the wax paper as best you can from the bore. Don't worry if some still remains, it will be expelled out during motor firing.

15. You now have a completed fuel grain.
16. Remove the other grains from the molds in the same manor.

MOTOR ASSEMBLY

1. Insert all three grains into the “TOP” of the 11-1/2” PVC pipe that was cut earlier and push them all the way to the “BOTTOM”. Try to make sure that all 3 grains are seated on top of each other.

2. The last grain should be even with the “BOTTOM” of the pipe.

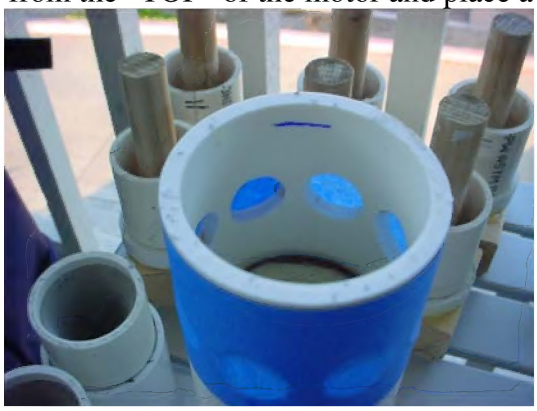
3. Cut a piece of 110 pound cardstock to cover the bore. This prevents the PourStone from entering the bore.

4. Mix up enough 5 minute epoxy to cover the top of the fuel grain and the edges where the grains touch the PVC pipe.

5. Once the top is covered, place the cardstock disc over the bore hole and seal it down with epoxy. Make sure that all of the ends are sealed; otherwise the PourStone can enter the bore which, if not caught in time, can ruin the motor.

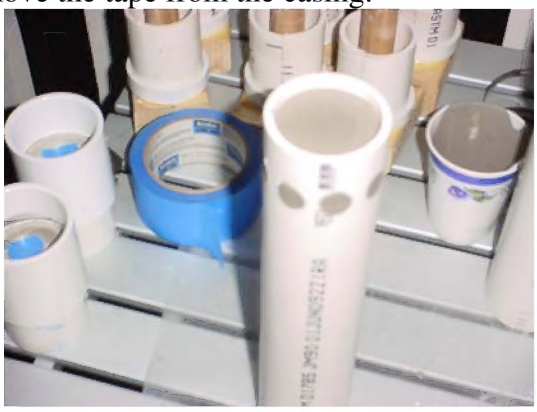
6. Let this dry completely (30 minutes).
7. Wrap masking tape or painter's tape around the "TOP" of the motor case to cover up the 5/8" holes.

8. Measure down ¼” from the “TOP” of the motor and place a mark.



9. Mix up enough PourStone to fill the “TOP” of the motor case up to the mark that was drawn.

10. Let this sit for an hour before moving it and removing the tape.
11. After an hour, remove the tape from the casing.



12. Inspect the “pins” that were created for any voids. If there is any, simply mix up more PourStone and fill in the voids and let it dry.

13. Place a piece of masking tape or painter's tape over the nozzle throat. This helps to keep moisture from entering the fuel grains.

14. Place a bead of high temperature silicone or RTV along the edge where the nozzle and PVC coupler meet. Also place a bead on the "BOTTOM" end of the PVC pipe. This will be used to form a seal between the nozzle assembly and the chamber.

15. Using medium grey PVC cement, glue the 2" coupler/nozzle onto the 2" casing and let dry.

16. The motor is now complete.

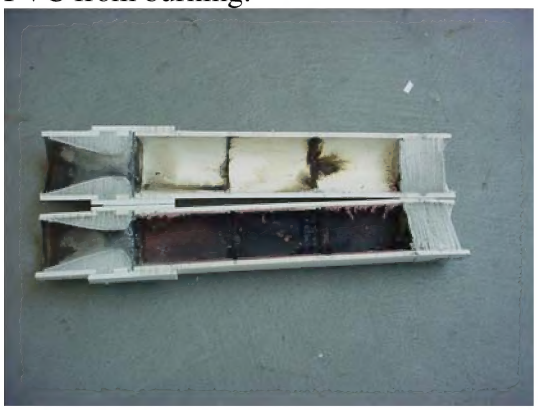
Congratulations!! You just made a 3-grain segmented rocket motor!

Special thanks to Dan at Inverse Engineering (http://www.inverseengineering.com) and Richard Nakka of Nakka Rocketry (http://www.nakka-rocketry.net) for their input and information that was used to put this tutorial together.

Notes:

1. Nozzle and Divergent Cone Diagrams at Bottom of Page (Dan @ Inverse Engineering): http://www.inverseengineering.com/Pages/2002/Ignis%20project/Ignis%20engine%20casing%20and%20nozzle/Page%2001.html

An expended 3-grain motor after firing. Notice how the propellant liners help prevent the PVC from burning.



I have also made a 4-Grain motor using this method with success.